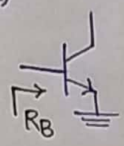
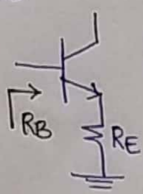
BJT (npn)

(1)



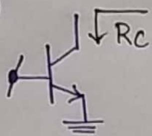
$R_B = r_\pi$

(2)



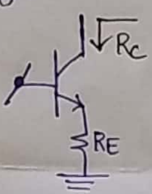
$R_B = r_\pi + (\beta+1)R_E$

(3)



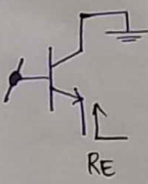
$R_C = r_o$

(4)



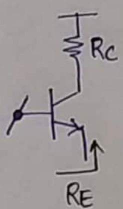
$R_C = g_m r_o (R_E \| r_\pi) + r_o + R_E \| r_\pi$

(5)



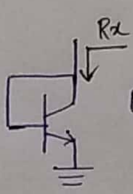
$R_E = \frac{1}{g_m} \| r_o \| r_\pi$

(6)



$R_E = \frac{R_C + r_o}{1 + g_m r_o} \| r_\pi$

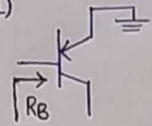
(7)



$R_x = r_\pi \| r_o \| \frac{1}{g_m}$

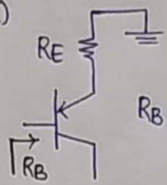
BJT (pnp)

(1)



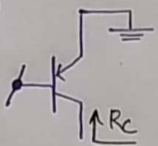
$R_B = r_\pi$

(2)



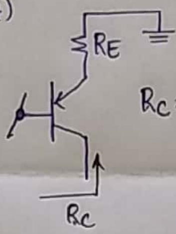
$R_B = r_\pi + (\beta+1) R_E$

(3)



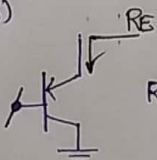
$R_C = r_o$

(4)



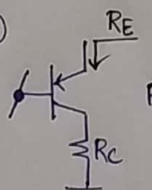
$R_C = g_m r_o (R_E \| r_\pi) + r_o + R_E \| r_\pi$

(5)



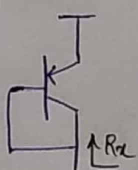
$R_E = \frac{1}{g_m} \| r_o \| r_\pi$

(6)



$R_E = \frac{R_C + r_o}{1 + g_m r_o} \| r_\pi$

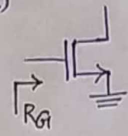
(7)



$R_x = r_\pi \| r_o \| \frac{1}{g_m}$

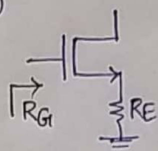
N-MOS

(1)



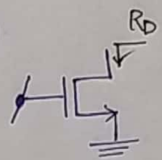
$R_G = \infty$

(2)



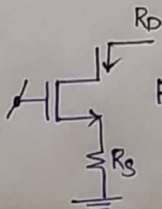
$R_G = \infty$

(3)



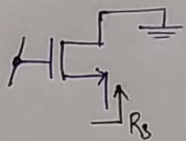
$R_D = r_o$

(4)



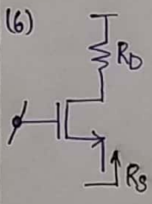
$R_D = g_m r_o R_S + R_S + r_o$

(5)



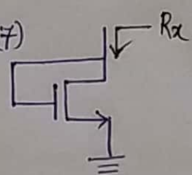
$R_S = \frac{1}{g_m} \| r_o$

(6)



$R_S = \frac{r_o + R_D}{1 + g_m r_o}$

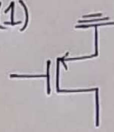
(7)



$R_x = r_o \| \frac{1}{g_m}$

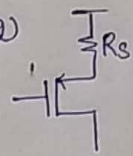
P-MOS

(1)



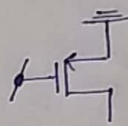
$R_G = \infty$

(2)



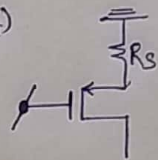
$R_G = \infty$

(3)



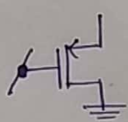
$R_D = r_o$

(4)



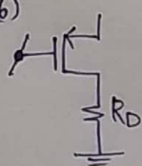
$R_D = g_m r_o R_S + R_S + r_o$

(5)



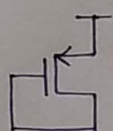
$R_S = \frac{1}{g_m} \| r_o$

(6)



$R_S = \frac{r_o + R_D}{1 + g_m r_o}$

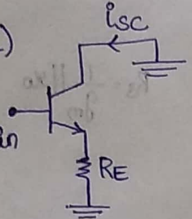
(7)



$R_x = r_o \| \frac{1}{g_m}$

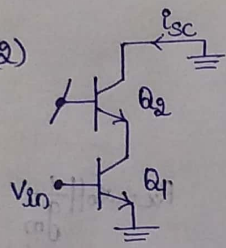
BJT (npn)

(1)



$$G_m = \frac{g_m r_o r_\pi - R_E}{R_E(r_o + r_\pi) + r_o r_\pi (1 + g_m R_E)}$$

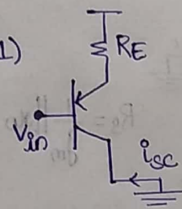
(2)



$$G_m = \frac{g_{m_1} r_{o_1}}{r_{o_1} + \frac{r_{o_2}}{1 + g_{m_2} r_{o_2}} + \frac{r_{o_1} r_{o_2}}{(1 + g_{m_2} r_{o_2}) r_{\pi_2}}}$$

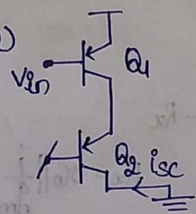
BJT (npn)

(1)



$$G_m = \frac{g_m r_o r_\pi - R_E}{R_E(r_o + r_\pi) + r_o r_\pi (1 + g_m R_E)}$$

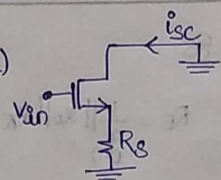
(2)



$$G_m = \frac{g_{m_1} r_{o_1}}{r_{o_1} + \frac{r_{o_2}}{1 + g_{m_2} r_{o_2}} + \frac{r_{o_1} r_{o_2}}{(1 + g_{m_2} r_{o_2}) r_{\pi_2}}}$$

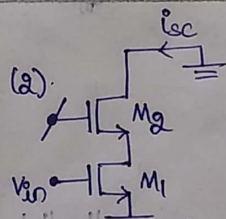
N-MOS

(1)



$$G_m = \frac{g_m}{1 + g_m R_S + \frac{R_S}{r_o}}$$

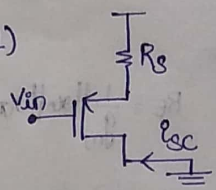
(2)



$$G_m = \frac{g_{m_1} r_{o_1}}{r_{o_1} + \frac{r_{o_2}}{1 + g_{m_2} r_{o_2}}}$$

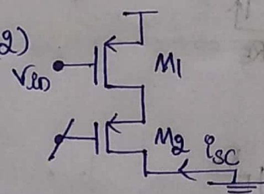
P-MOS

(1)



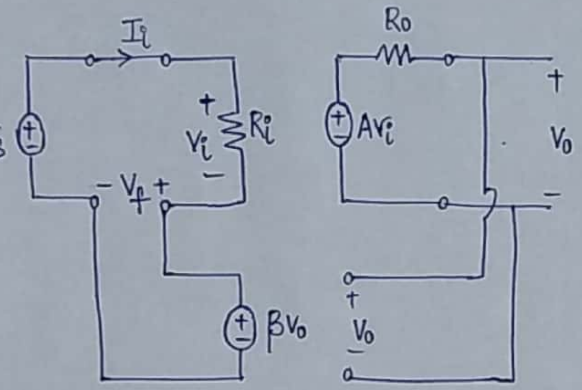
$$G_m = \frac{g_m}{1 + g_m R_S + \frac{R_S}{r_o}}$$

(2)



$$G_m = \frac{g_{m_1} r_{o_1}}{r_{o_1} + \frac{r_{o_2}}{1 + g_{m_2} r_{o_2}}}$$

Voltage amplifier : A_v



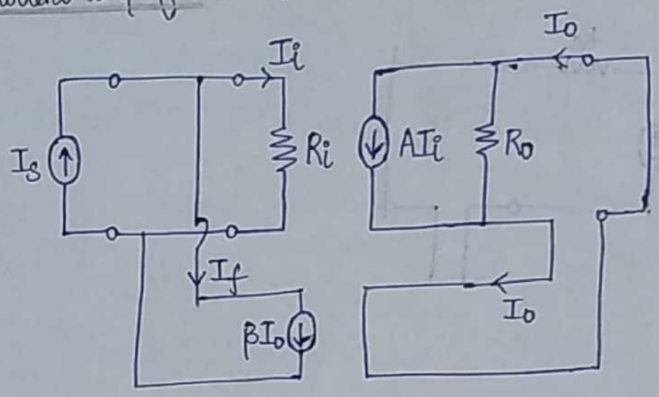
$R_{if} = R_i(1+A\beta)$; $R_{of} = \dfrac{R_o}{1+A\beta}$;

$$A_f = \frac{A}{1+\beta A}$$

Series – Shunt feedback

Voltage – Voltage feedback
(sense) (return)

Current amplifier : A_i



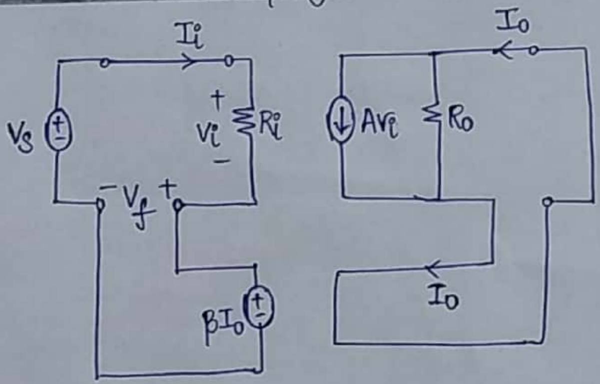
$R_{if} = \dfrac{R_i}{1+A\beta}$; $R_{of} = R_o(1+A\beta)$;

$$A_f = \frac{A}{1+\beta A}$$

Shunt – Series feedback

Current – Current feedback
(sense) (return)

Transconductance amplifier : G_m



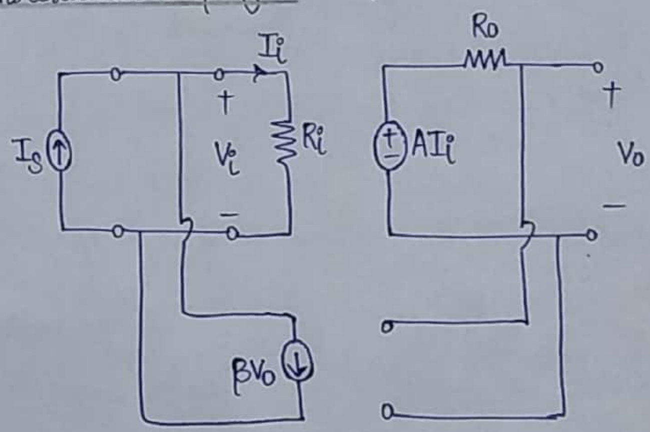
$R_{if} = R_i(1+A\beta)$; $R_{of} = R_o(1+A\beta)$;

$$A_f = \frac{A}{1+A\beta}$$

Series – Series feedback

Current – Voltage feedback
(sense) (return)

Transresistance amplifier : R_m

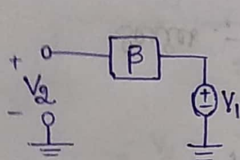


$R_{if} = \dfrac{R_i}{1+A\beta}$; $R_{of} = \dfrac{R_o}{1+A\beta}$; $A_f = \dfrac{A}{1+A\beta}$

Shunt – Shunt feedback

Voltage – Current feedback
(sense) (return)

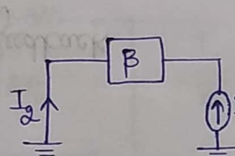
Feedback Factor (β)



$\beta = \frac{V_2}{V_1}$

Series - Shunt

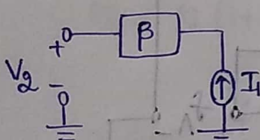
Voltage - Voltage



$\beta = \frac{I_2}{I_1}$

Shunt - Series

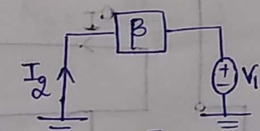
Current - Current



$\beta = \frac{V_2}{I_1}$

Series - Series

Current - Voltage

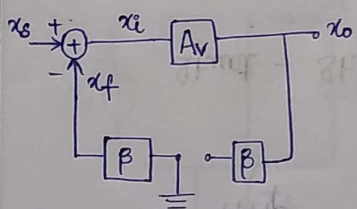


$\beta = \frac{I_2}{V_1}$

Shunt - Shunt

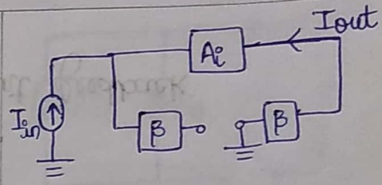
Voltage - Current

Connections of Sense duplicate and Return duplicate



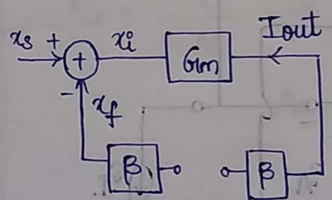
Series - Shunt

Voltage - Voltage



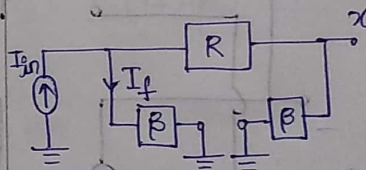
Shunt - Series

Current - Current



Series - Series

Current - Voltage

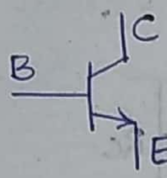


Shunt - Shunt

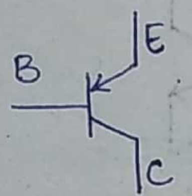
Voltage - Current

BJT & MOS

① NPN :



PNP :



②

$$I_C = I_S \cdot e^{V_{BE}/V_T} \cdot \left(1 + \frac{V_{CE}}{V_A}\right)$$

③

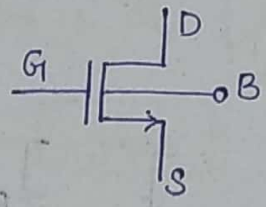
$$g_m = \frac{I_C}{V_T}$$

$$r_o = \frac{V_A}{I_C}$$

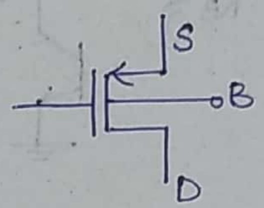
$$r_\pi = \frac{\beta}{g_m}$$

$$\beta = \frac{I_C}{I_B}$$

① NMOS :



PMOS :



②

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \left(2(V_{GS} - V_{TH}) V_{GS} - V_{GS}^2 \right)$$

—— triode

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS})$$

—— saturation

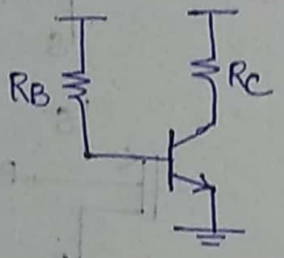
③

$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})$$

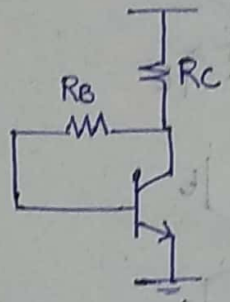
$$r_o = \frac{1}{\lambda I_D}$$

Biasing Schemes :

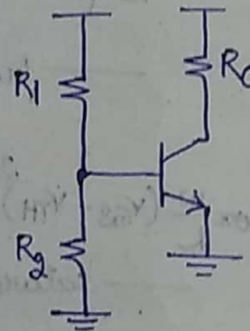
BJT :



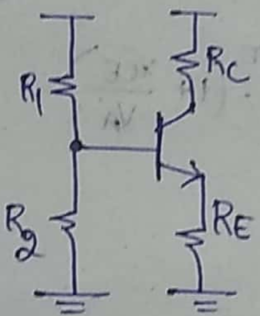
simple biasing



self biasing

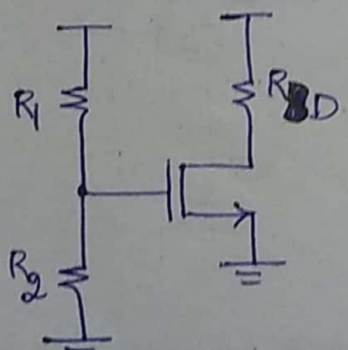


resistive divider biasing

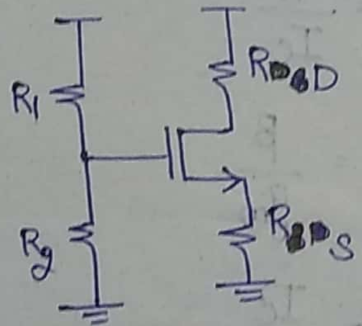


emitter degeneration biasing

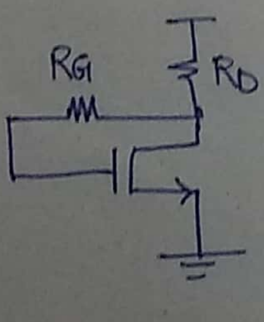
MOS :



resistive divider biasing



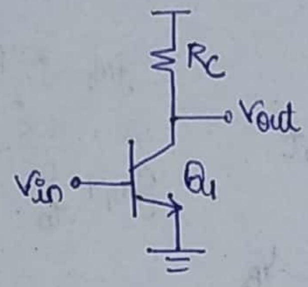
source degeneration biasing



self biasing

Common Emitter :

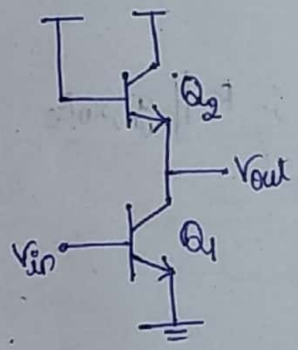
(a) Resistive Load :



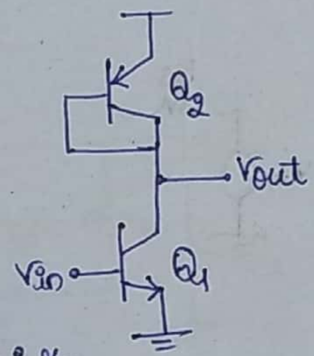
g_{m_1} ; R_C ; r_{π_1}

$\boxed{-g_{m_1} R_C}$

(b) Diode Connected load :

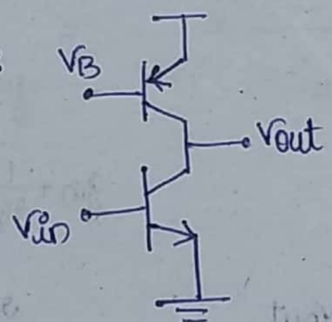


g_{m_1} ; $1/g_{m_2}$; r_{π_1}



$\boxed{\dfrac{-g_{m_1}}{g_{m_2}}}$

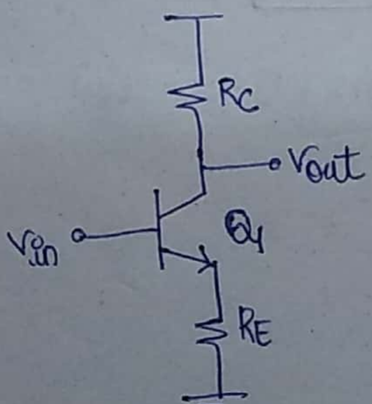
(c) Current Source Load :



g_{m_1} ; $r_{o_1} || r_{o_2}$; r_{π_1}

$\boxed{-g_{m_1}(r_{o_1} || r_{o_2})}$

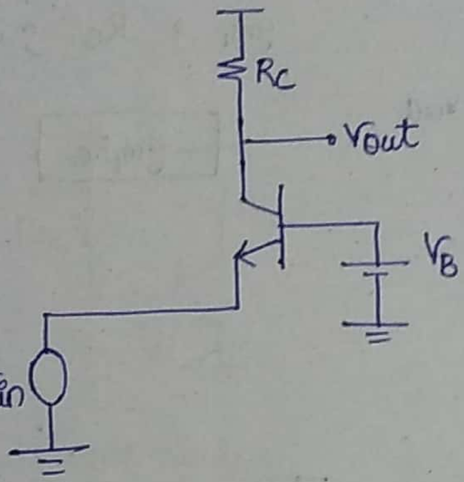
(d) Emitter Degenerated :



$\dfrac{g_{m_1}}{1+g_{m_1}R_E}$; $\cong R_C$; $r_{\pi_1}+(\beta+1)R_E$

$\approx \boxed{-R_C/R_E}$

Common base :



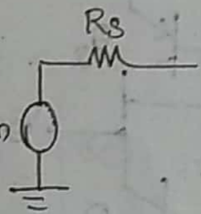
g_{m_1} ; $R_C \| r_o$; $\dfrac{R_C + r_o}{1 + g_m r_o} \| r_\pi$

$\parallel\!\parallel$

$g_{m_1} + \dfrac{1}{r_o}$

$\boxed{+\left(g_m + \frac{1}{r_o}\right)(R_C \| r_o)}$

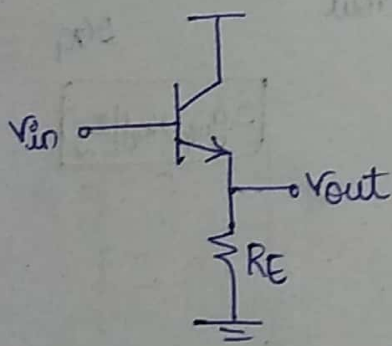
if



$\dfrac{g_{m_1}}{1 + g_{m_1} R_S}$; $R_C \| g_m r_o R_S$

Common collector:

Emitter Follower



$g_m + \dfrac{1}{r_\pi}$; $R_E \| r_{\pi_1} \| \dfrac{1}{g_{m_1}} \| r_{o_1}$;

$r_{\pi_1} + (\beta + 1) R_E$

$\cong \boxed{g_{m_1} \cdot \dfrac{R_E}{1 + g_m R_E}}$

BJT

* CB : $C_\mu = \dfrac{C_{\mu 0}}{\left(1+\frac{V_{CB}}{V_0}\right)^m}$

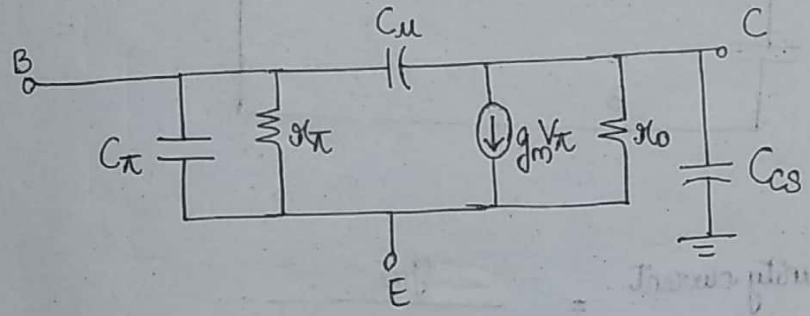
* Base - diffusion cap.

$C_{de} = \tau_F \cdot \dfrac{I_C}{V_T}$

* EB : $C_{je} \approx 2C_{je_0}$ — bias of 0V

$C_\pi = C_{je} + C_{de}$

* C_{CS} - collector substrate cap.



f_T : unity current gain frequency $= \dfrac{g_m}{2\pi(C_\pi + C_\mu)}$

MOS

* • $C_{gs} = C_{gd} = \frac{1}{2} WLC_{ox} + WC_{ov}$ } Triode

• $C_{gs} = \frac{2}{3} WLC_{ox} + WC_{ov}$

$C_{gd} \approx 0 + WC_{ov}$ } → Saturation

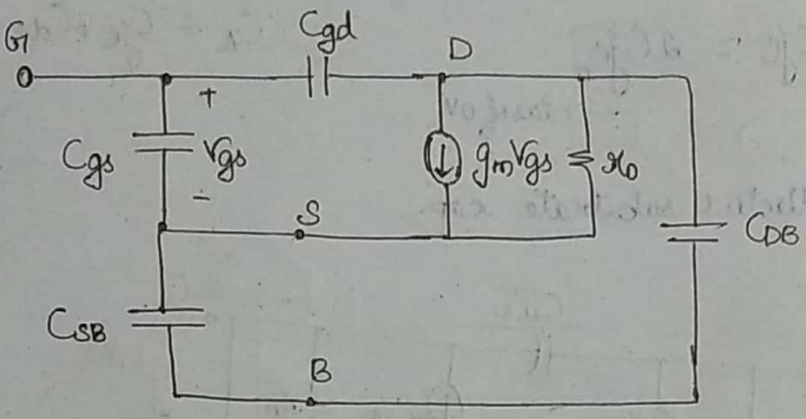
• $C_{gs} = C_{gd} \approx 0 + WC_{ov}$ } → Cut off

WC_{ov} — overlap capacitance.

Scanned by CamScanner

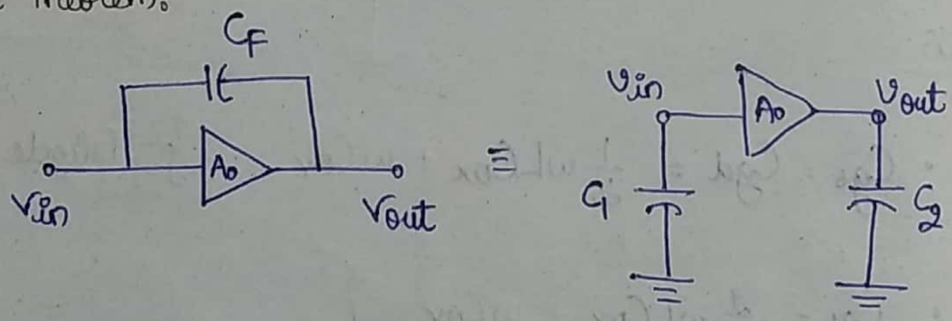
* C_{sb} and C_{Db} – (RB) depletion cap.

$$C_{Sb} = \frac{C_{Sbo}}{\sqrt{1+\frac{V_{Sb}}{V_0}}} \qquad C_{Db} = \frac{D_{Dbo}}{\sqrt{1+\frac{V_{Db}}{V_0}}}$$



f_T : unity current gain frequency $= \dfrac{g_m}{2\pi(C_{gs}+C_{gd})}$

Miller Theorem:



$$C_1 = C_F(1-A_0)$$

$$C_2 = C_F\left(1-\frac{1}{A_0}\right)$$